VERE

VERE: Virtual Embodiment and Robotic Re-Embodiment

Integrated Project no. 257695

FP7-ICT-2009-5

WorkPackage WP2 The Embodiment Station

Deliverable no. D2.3

First prototype of Embodiment station

Authors list:

Antonio Frisoli[1], Massimo Bergamasco[1], Daniele Leonardis[1],

Franco Tecchia[1], Massimiliano Solazzi[1],

Basilio Lenzo[1], Marcello Carrozzino[1], Fabio Salsedo[1],

[1] PERCRO TeCIP Institute, SSSA

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EXECUTIVE SUMMARY

This deliverable is an accompanying document to the delivery of the first prototype of the Embodiment Station. The prototype is documented as well through a video that is provided together with this document.

The system has been implemented and developed at Pisa, at SSSA premises, as a result of the efforts of first period of research of numerous partners involved in WP2 and collaboration activities across different WPs.

The platform is a multisensory station that allows the user to perceive a highly immersive simulation of embodiment within the surrogate body, that might consists either of a virtual avatar or a remote robot.

In this document we outline the main characteristics of the platform, with particular reference to the main components that are associated to the different sensory modalities.

Deliverable Identification Sheet

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Authors (Partner)	Antonio Frisoli[1], Massimo Bergamasco[1], Daniele Leonardis[1], Franco Tecchia[1], Massimiliano Solazzi[1], Basilio Lenzo[1], Marcello Carrozzino[1], Fabio Salsedo[1], 1 SSSA			
Responsible Author	Massimo Bergamasco, Antonio Frisoli	**Email**	bergamasco@sssup.it, a.frisoli@sssup.it	
	Partner SSSA	**Phone**		
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1 THE EMBODIMENT STATION

The Embodiment station is conceived as an integrated system for interfacing the inert user with a robotic or virtual avatar body. Afferent signals, generated by the interaction of the avatar body within the virtual or remote environment, and by the proprioception of the avatar body itself, are provided to the user through multi-sensory pathways: vestibular, tactile, kinesthetic and visual feedback signals are transmitted by dedicated actuated modules of the embodiment station. Efferent signals, generated by the user body, are acquired by sensing modules of the embodiment station and sent to the avatar body as control and monitoring data. The efferent signals modules are conceived for being used by the inert user, with eventually limited or absent residual motor capabilities, thus they are based on the acquisition of the user intentions directly at brain and gaze level.

Fig 1. Overview of the embodiment Station

The Embodiment station is composed of the following modules:

Afferent signals

- Vestibular module (mobile platform)
- Visual module (Head-Mounted-Display / Micro-Cave)
- Proprioceptive vest (distributed system generating kinaesthetic illusion at limb level)
- Tactile vest (distributed system simulating impact cues)

Efferent signals

- Brain-Computer-Interface (EEG BCI based on motor imagery and visually evoked potential)
- Eye-tracking module

There is a growing interest in systems for providing telexistence and telepresence conditions in different fields, ranging from operation in hazardous environments to remote surgery.

First cockpit for telexistence and humanoid robot control were proposed by Susumu Tachi (Tachi, Komoriya et al. 2003) with retro-reflective projective technology (Tachi 2003), and then recently evolved in the Telesar V platform (Fernando, Furukawa et al. 2012).

The main technological contribution is that for the first time the embodiment station developed in VERE does include proprioceptive and vestibular sensory feedback and motor input directly interpreted from Brain activity, to allow the telepresence experience in absence of any actual movement of his/her body.

The subject experimenting the Embodiment Station will be able to control by his thought the walking of the remote robotic surrogate or avatar, while he will get back a perception of walking illusion through proprioceptive stimulation at leg joints.

1.1 Vestibular Module

The vestibular module is implemented by means of a mobile platform which the user seat is mounted on. Through controlled trajectories the mobile platform simulates the movements of the avatar body (movements are referred as the translation and rotation of the head), thus stimulating with congruent stimuli the vestibular system of the user.

The mobile platform is a Moog Stewart platform with parallel kinematics. The upper platform can be moved in the space with 6 DOF (three positions and three rotations) with a maximum payload of 400 Kg.

The simulation of the surrogate body movements is optimized for reproducing linear accelerations and angular velocities within the limited workspace of the mobile platform. A digital filter, implemented on a dedicated control board, computes in real-time the trajectory of the platform on the basis of the acceleration and angular velocity reference sent over the net. It also takes in account for compensation the frequency components of the reference signals and the position of the platform with respect to the workspace limits.

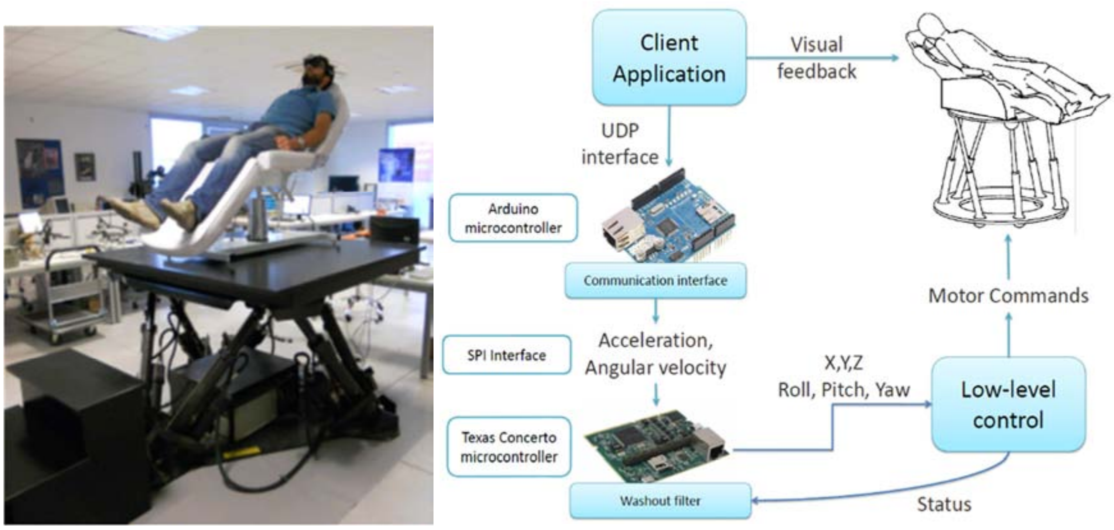
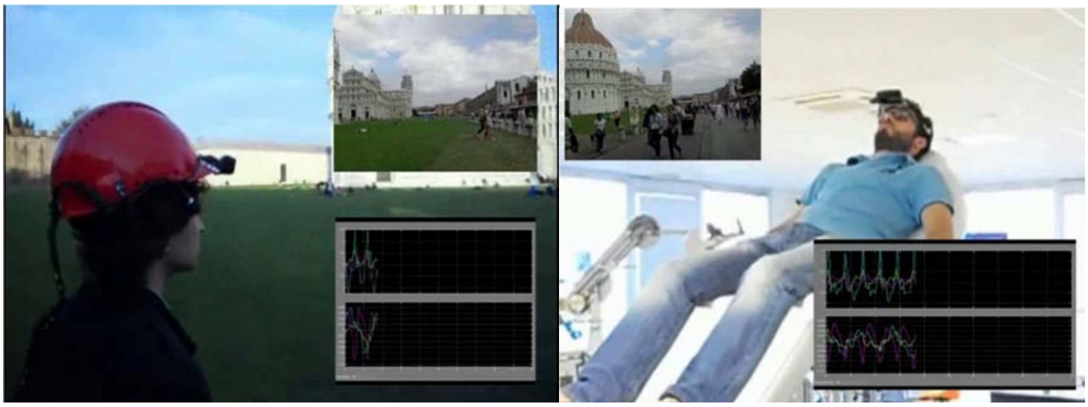


Figure 1 The vestibular module and overview of the mobile platform control system

In order to demonstrate the potential of the developed platform, a specific equipment was developed to acquire acceleration, angular velocity, video and stereo audio data. The system is a helmet with two cameras mounted on the top of it, one IMU unit mounted in the upper part and two microphones on the two sides.

The recording unit allows to record a synchronized multisensory stream of data Figure 2.left., that can be then reproduced on the embodiment station Figure 2.right.

The components were successfully used to record a virtual walking through Miracle Square and to reproduce the experience in first person perspective inside the Embodiment Station.



(left) (right)

Figure 2 Example of a virtual tour in Miracle Square inside the Embodiment Station

1.2 Visual Module

A Head-Mounted-Display provides the user a stereoscopic visual feedback acquired through the eyes of the surrogate body. In case of a robotic embodiment, the visual feedback is intended to be recorded and sent as a video stream in real-time through cameras mounted on the robotic surrogate. For the virtual embodiment condition, visual feedback is provided by a real-time rendering of the virtual scene.

A Head-Mounted-Display, supporting stereoscopy has been used for the visual module of the embodiment station. For the virtual condition, the real-time rendering and the design of the virtual environment is developed with the XVR IDE.

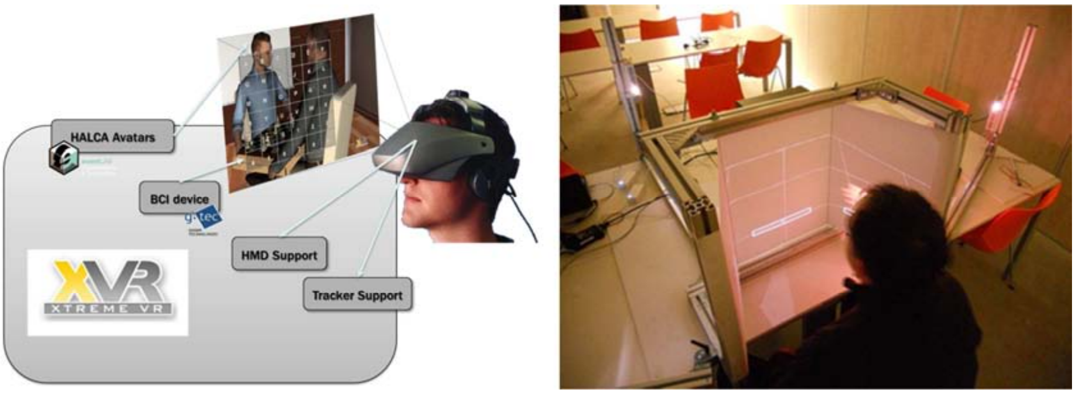


Figure 3 The two approaches to visual rendering in the Embodiment Station. The HMD and the miniCAVE solution

As an alternative solution for virtual rendering, a passive stereoscopic 3-4 walls solution was specifically developed and tested. As shown in Figure 3 the miniCAVE solution is capable to display objects within a broader field of view and without requiring wearing of HMD from the subject. This might be particularly indicated for the experiments in which the HMD should be worn for long periods of time.

1.3 Proprioceptive Vest

The proprioceptive vest is a module of the Embodiment station capable of eliciting controlled illusory movements into the inert user, with the purpose of simulating the surrogate body's pose and velocities of the limbs.

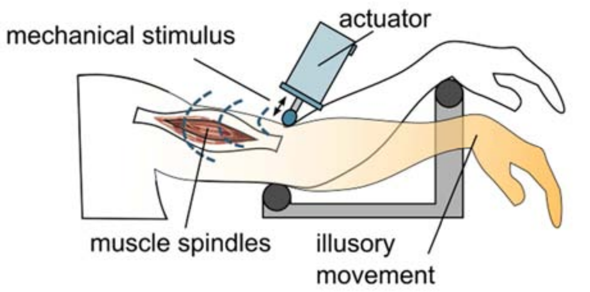


Figure 4 The Proprioceptive vest applied at the upper limb

The proprioceptive vest is composed by a set of specific high-bandwidth linear actuators distributed over the joints of the user's limbs. In particular, each actuator exerts modulated vibrating patterns in proximity of muscle tendons: the mechanical stimuli activate muscle spindles Ia afferents, thus arising into the CNS the perception of a kinesthetic illusion related to the extension of the vibrated muscle.

Dedicated control and driving electronics have been developed for each linear actuator, thus being able to independently stimulate each tendon with accurate vibration patterns. By the independent stimulation of different tendons, complex, multi-d.o.f. movements can be evoked into the inert user, accordingly to the avatar's body limbs position.

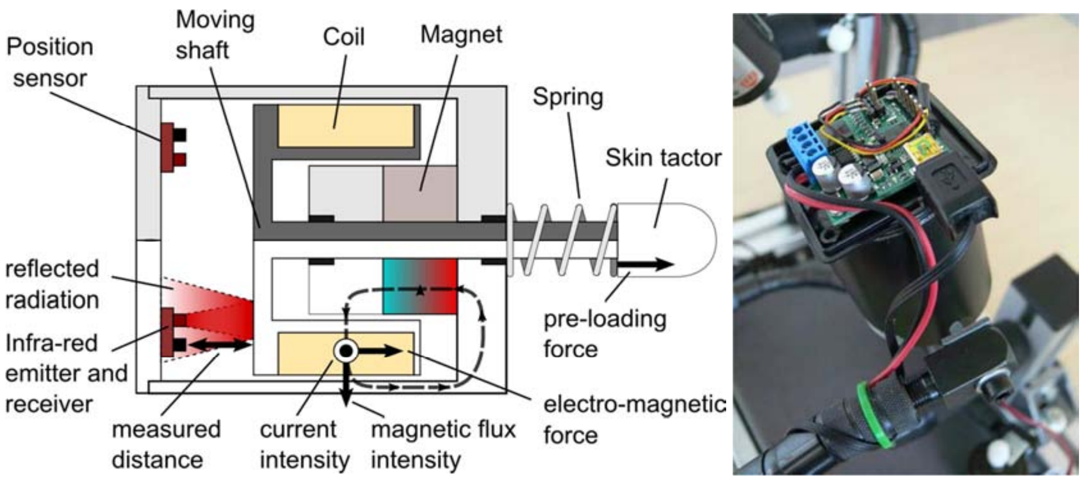


Figure 5 Internal scheme of the proprioceptive vest actuator and overview of the dedicated control board

1.4 Tactile Vest

The tactile feedback is integrated into the embodiment station by means of a wearable tactile vest. The vest implements actuators distributed over the user body, delivering impact and pressure cues generated by the interaction of the avatar body into the remote or virtual environment.

Figure 6 Detail of the tactile vest actuators and Tactile vest modules worn onto the user's torso

Since the perception of impacts in humans is proportional to the delivered kinetic energy, the tactile vest actuators were chosen optimizing the maximum delivered kinetic energy with respect to maximum allowable size, weight and working temperature. Rotary electromagnetic motors were coupled with a skin tactor mounted on the output shaft, and fixed on elastic bands that can be worn onto the user's torso and limbs.

The control electronics of the tactile vest was implemented through a module composed of a micro-controller board and dedicated H-bridges ICs for each actuator. A single module can control a set of 12 tactile actuators, generating impacts with controllable kinetic energy.

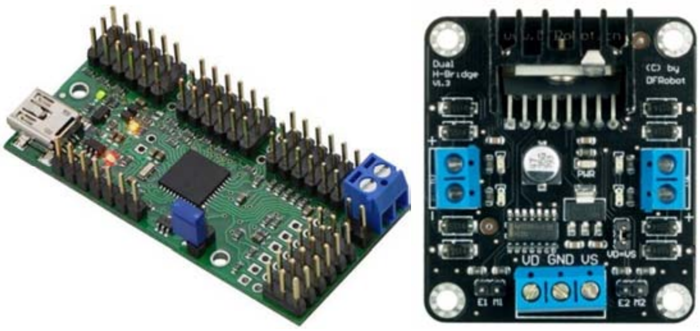


Figure 7 Overview of the micro-controller board (Pololu Micromaestro) and h-bridges ICs implemented into the Tactile Vest

The overall integration of tactile and proprioceptive components was achieved in a paradigmatic application developed for social interaction with virtual avatars, as shown in Figure 8.

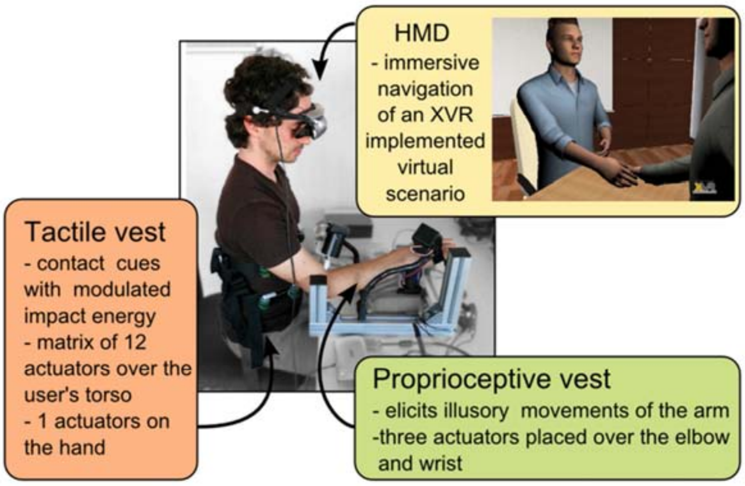


Figure 8 The proprioceptive and tactile vests integrated in the social application scenario

In this application scenario the user is embodied inside a virtual avatar, whose movement can be controlled by means of a BCI interface, as outlined in the next section. The feeling of embodiment is enhanced by the mechanical stimulation of movements, that even with immobile limbs, creates a strong feeling of movement of the virtual body.

By wearing the tactile vest as well, the subject can experience also the sensation of touch another virtual avatar or of being touched by means of a visuo-tactile-proprioceptive congruent stimulation, as shown in Figure 9. This open the way to the design of numerous applications involving the feeling of body ownership in contexts of social interaction.

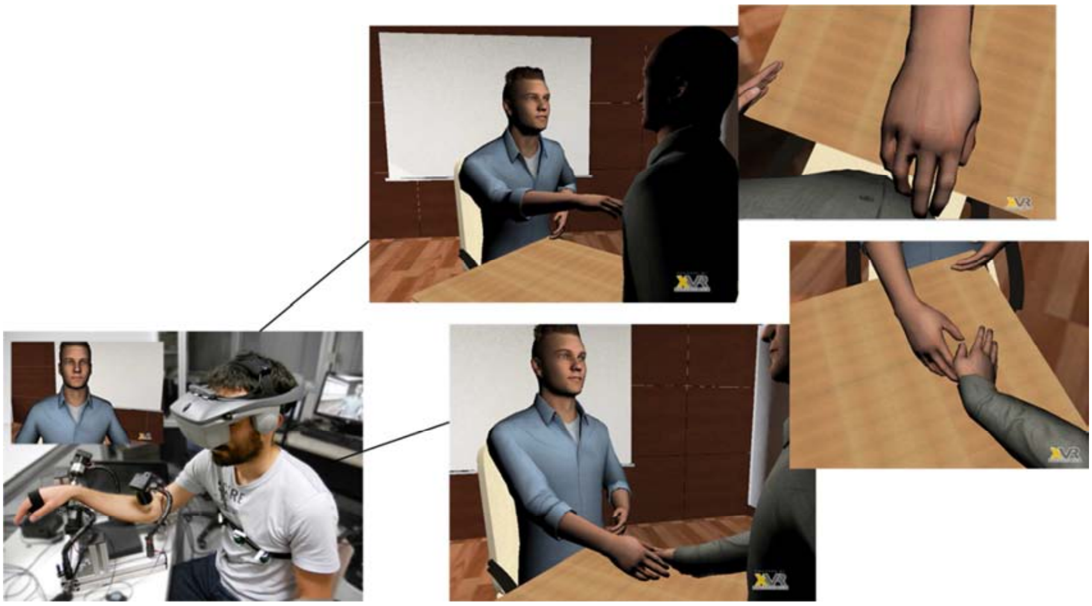


Figure 9 Experience your virtual body through the Embodiment Station

1.5 Brain Computer Interface

A non-invasive EEG brain computer interface is implemented into the Embodiment Station, acquiring efferent signals from the inert user at the brain activity level. The motor imagery paradigm allows the user to control movements of the avatar body directly performing a mental execution of the motor task.

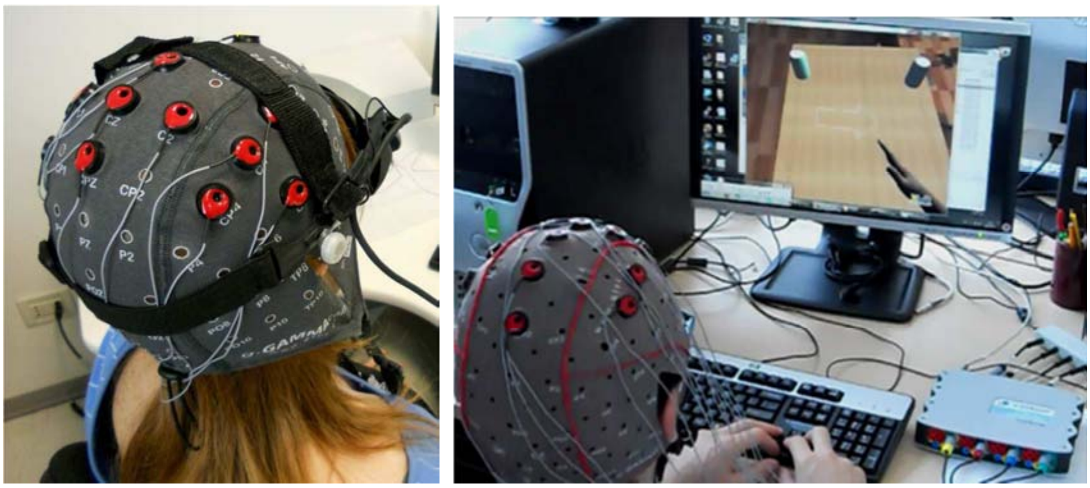


Figure 10 The EEG brain computer interface based on motor imagery, here shown for the virtual embodiment condition.

The EEG signals are recorded and on-line processed by the BCI in order to send control commands to the avatar body in real-time. The raw data is conditioned, spatially and frequency filtered, in order to minimize the effects of artifacts and environmental noise superimposed to the low-amplitude EEG signals. Then, features related to the Event-Related-Desynchronization, generated by motor imagery, are extracted and classified.

The spatial filtering and classification parameters are adaptively tuned for each subject and session (Common Spatial Patterns and SVM classifier algorithms) for overcoming differences in features location and small discrepancies due to electrodes position and skin electrical conductivity.

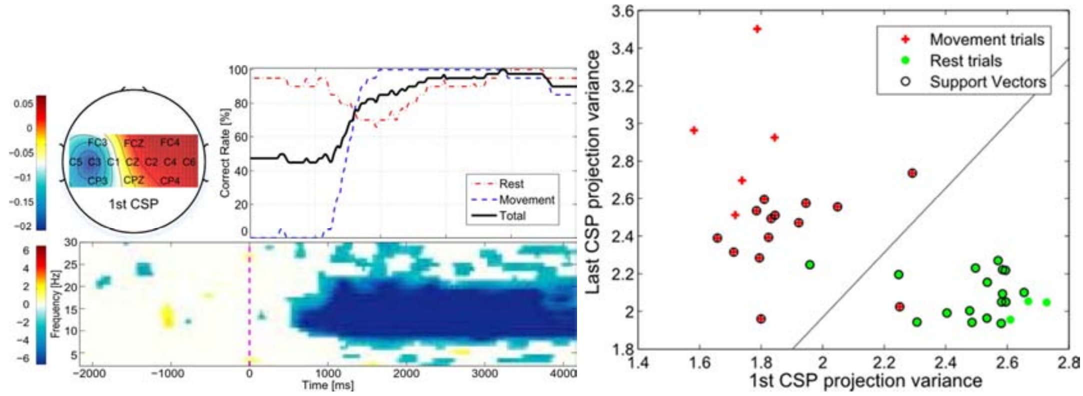


Figure 11 brain activity processing and classification performed by the BCI

1.6 The kinesthetic vest

The integration of kinesthetic sensory feedback inside the embodiment station was achieved through the development of a light exoskeleton system in dual arm configuration characterized with a new design.

The system, whose CAD model is shown in Figure 12, is currently being assembled, due to some delays occurred in parts manufacturing by precision machining suppliers (see Figure 13).

Figure 12 The kinesthetic vest for the moving participant

Figure 13 First prototype realization of the exoskeleton solution for the kinaesthetic vest

2 PRESS REVIEW

The launch of the “Embodiment Station” has been advertised through the media that have dedicated a broad coverage on press and media.

In particular, it is remarkable to outlight that Euronews dedicate a space on air in November in the "Futuris" program . Here's the airing schedule of the on euronews

Central European Time

- Thursday 15th: 18:45, 01:45
- Friday: 09:45, 13:45
- Saturday: 06:45, 12:15, 17:45, 22:45
- Sunday: 10:45, 14:45, 20:45
- Monday: 09:15, 18:45, 01:45
- Tuesday: 13:15, 18:15, 01:45
- Wednesday: 10:15, 16:45, 02:45

The program was made available in all the eleven languages on our website:

- English: http://www.euronews.com/2012/11/13/a-world-without-limits/
- French: http://fr.euronews.com/2012/11/13/un-monde-virtuel-sans-limites/
- German: http://de.euronews.com/2012/11/13/ein-wackelstuhl-hilft-behinderten-beim-gefuehlten-gehen/
- Italian: http://it.euronews.com/2012/11/13/la-ricerca-che-avvicina-il-mondo-virtuale-a-quello-reale/
- Spanish: http://es.euronews.com/2012/11/13/un-mundo-sin-limites/
- Portuguese: http://pt.euronews.com/2012/11/13/um-mundo-sem-limitaces/
- Russian: http://ru.euronews.com/2012/11/13/a-world-without-limits/
- Arabic: http://arabic.euronews.com/2012/11/13/a-world-without-limits/
- Turkish: http://tr.euronews.com/2012/11/13/sanal-gerceklik-fiziksel-engelleri-ortadan-kaldirabilir-mi/
- Persian: http://persian.euronews.com/2012/11/13/a-world-without-limits/
- Ukrainian: http://ua.euronews.com/2012/11/13/a-world-without-limits/

Also Italian newspapers and television dedicated room to the Embodiment Station. In particular we had a video on line entitled “Virtual Reality like the Avatar movie” on the ANSA, the Italian Press Agency, that is available from here http://www.ansa.it/scienza/notizie/videogallery/ultimi/2012/11/26/Realta-virtuale-come-fil-Avatar-_7859847.html

The video has been enclosed as well as annex to this deliverable.

Moreover on November 30, 2012 the main TC channel RaiUno has dedicated a report in the program UnoMattina, showing the video/image from the Embodiment Station, and with an interview to prof. Antonio Frisoli, attending in the studios.

Moreover the following articles appeared (in Italian) on Italian newspaper on Saturday Nov 24, 2012:

Corriere Fiorentino:	*Avatar, dal cinema alla realtà. La scienza crea mondi virtuali*
Tirreno Pisa:	*Avatar nasce al Sant'Anna la realtà virtuale pare vera*
Unita` Toscana:	*Al Sant'Anna per vivere come Avatar*
Qn:	*La foto del giorno*
Nazione:	*Virtuale e reale più vicini con la Sant'Anna*
INToscana:	*Se "Avatar" è realtà, ecco corpo virtuale*

3 REFERENCES

Fernando, C. L., M. Furukawa, et al. (2012). Design of TELESAR V for transferring bodily consciousness in telexistence. Intelligent Robots and Systems (IROS), 2012 IEEE/RSJ International Conference on, IEEE.

Tachi, S. (2003). Telexistence and retro-reflective projection technology (RPT). Proceedings of the 5th Virtual Reality International Conference (VRIC2003) pp, Citeseer.

Tachi, S., K. Komoriya, et al. (2003). "Telexistence cockpit for humanoid robot control." Advanced Robotics **17**(3): 199-217.